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DEFINING POSTMORTEM CHANGES IN WESTERN MONTANA:
A LONGITUDINAL STUDY OF THE RATE AND SEQUENCE OF
SURFACE AND BURIAL DECOMPOSITION

By

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Thesis

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for the degree of

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Defining Postmortem changes in western Montana: A Longitudinal Study of the Rate and Sequence of Surface and Burial Decomposition

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Estimating time since death is difficult because of the multitude of factors that can alter postmortem change. Initial research conducted in western Montana indicates that decomposition does not follow the patterns found in other geographic locations. The purpose of this study is to better define how western Montana's unique environmental factors affect the rate and pattern of decomposition of surface remains and buried remains.

In May 2012 one mature pig (*Sus scrofa*) was placed on the surface and a second pig was buried. Throughout a nine-month period the following variables were monitored for the surface pig: rate and pattern of decomposition, climatic variables, internal temperature, and entomological activity. The following variables were monitored for the buried pig: ambient temperature, internal temperature, relative humidity, vegetation changes, pH levels, animal patterns, and insects. The results from this study indicate that regardless of whether a body is deposited on the surface or buried, mummification of external tissues occurs and is persistent for at least nine-months in the absence of animal scavenging. The ultimate result of this study contributes to building a baseline data set for documenting decomposition in western Montana's cool and arid climate.

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Chapter 1 Introduction

Estimating time since death is difficult because of the multitude of factors that can alter its postmortem changes (Bass, 1997). Our understanding of human decay rates is still incomplete. Forensic anthropologists and law enforcement agencies have a limited amount of information about time since death, due to varying environmental factors making taphonomic changes different in all areas (Haglund and Sorg, 1997a; Haglund and Sorg, 1997b). Due to its unique climate and altitude, western Montana's decomposition rates are different from rates in other parts of the country. Previous research studied decomposition rates at a higher altitude (Gonder, 2008; Dudzik, 2009; Parsons, 2009) and in the Missoula area (Terneny, 1997) although not enough to create a decomposition baseline. In addition, very little research has been conducted on decomposition of buried specimens in the cooler arid climate of western Montana (Terneny, 1997).

Most research regarding time since death intervals has been conducted at the Anthropological Research Facility in Tennessee or based on case studies. For forensic anthropologists helping law enforcement, estimating time since death is crucial to investigations (Haglund and Sorg, 1997b). Environmental factors such as temperature, humidity, precipitation, and insect activity all affect decomposition rates. Better understanding how these factors influence taphonomic changes, such as decomposition, can assist forensic anthropologists and law enforcement in estimating time since death.

Recent research suggests that one of the most important factors of decomposition is temperature. Megyesi et al. (2005) conducted research looking at 68 human cases throughout the continental United States, to determine the relationship of temperature to decomposition. They concluded that considering the temperatures to which a body was exposed might provide a more

accurate estimation of time since death. Interestingly enough, a case from Missoula, Montana was initially part of their research, however, it was classified as an outlier which was attributed to environmental factors not controlled for in their research.

Also, the soil composition in which an individual is buried will also affect taphonomic changes that occur (Turner and Wiltshire, 1999). Factors that affect burials include soil composition, soil pH, moisture content, humidity, and possible insect activity (Micozzi, 1991; Turner and Wiltshire, 1999; Dent et al., 2003; Wilson et al., 2007; Haslam and Tibbet, 2009; Janaway et al., 2009; Bachmann and Simmons, 2010; Carter et al., 2010; Schotsmans et al., 2011). Terneny (1997) found that in western Montana a buried pig underwent a much slower process of decomposition than one on the surface. Turner and Wiltshire (1999) conducted research in a heavy clay soil, with four-month-old dead pigs. From their research, they concluded that soil is an important variable for decomposition in a burial context.

The purpose of this current study is to gather information about the decomposition of specimens deposited both above ground and buried. This research will also help to continue the baseline decomposition research in the unique environment of western Montana. Also, this research may help in building a body of decomposition data for buried specimens, which decompose differently than specimens on the surface.

This research poses two hypotheses. The first hypothesis is that the rate and pattern of decomposition in western Montana will differ from other areas of the United States. The second hypothesis states the rate and pattern of burial decomposition in will differ from the rate and pattern of surface decomposition in western Montana.

This research consisted of two mature pigs as proxies for humans. One carcass was placed on the ground surface, and the other pig was buried at a depth of 2 feet. Both pigs were

deposited on 26 May 2012 in the Bitterroot Valley. The variables that were monitored for the surface pig were visual observations of color change, bloat, insect activity, and olfactory observations as well as were the ambient temperature at the site, the pig's internal temperature and the relative humidity at the site. The variables that were monitored for the buried pig were changes in animal activity, changes in vegetation, changes in soil color and pH, along with ambient temperature at the site, internal temperature of the pig and the relative humidity at the site.

Chapter 2 Literature Review

Forensic taphonomy is the study of postmortem processes. For decomposing or decomposed bodies this information may be used to better understand postmortem interval, and may subsequently help solve law enforcement cases (Tibbet and Carter, 2009). Therefore, close investigation of decomposition processes must be conducted in order to fully understand how environmental factors will affect the postmortem interval.

Galloway (1997) outlined five stages of decomposition (1) fresh; (2) early decomposition; (3) advanced decomposition; (4) skeletonization; and (5) extreme decomposition that are commonly used to label the stages of decomposition. The fresh stage of decomposition is generally described as no discoloration seen on any part of the cadaver's body (Galloway, 1997). Early decomposition is marked by discoloration of all parts of the body, and may include marbling, as well as the loss of bodily fluids from all orifices, and bloating of the abdominal cavity. The early stage of decomposition also sees the beginning of insect activity, and generally at this stage, blow flies and bottle flies lay their eggs in any wounds that are present or other warm, protected areas (Mann et al., 1990; Galloway et al., 1997). The early stage of decomposition ends with the release of decomposition gasses from the abdomen (loss of bloat) (Galloway, 1997). Advanced decomposition has large masses of maggots of the Calliphoridae (blow flies), Sarcophagidae (flesh flies), and Muscidae families (house flies) (Valdes-Perezgasga et al., 2010). Visually, advanced decomposition stage is seen as moist decomposition, with sagging of skin and the caving of abdominal cavity and areas of the face and neck, and mummification of parts of the body begins (less than fifty percent) (Galloway, 1997). The skeletonization stage of the decomposition process is the exposure of greasy bones, although there may be some retaining soft tissue, as well as bones with mummified tissue (less than fifty

percent), bones that are mostly dry but retain some grease. During the skeletonization stage, arthropods of the Staphylinidae (rove beetle), Dermestidae (skin beetles), Cleridae (red legged ham beetles), Anthocoridae (flower bugs), Formicidae (ants), Soliphugae (spiders), Isopoda (crustations), and Acari (mites and ticks) families can be found; however, usually at this point, fly larvae leave the carcass to pupate (Valdes-Perezgasga et al., 2010). Extreme decomposition is when bones that are exposed become dry and bleached, exfoliated with metaphyseal loss and exposure of cancellous bone in vertebrae and long bones (Galloway, 1997).

Unfortunately, little is known about the decomposition process that occurs for buried bodies, due to a lack of available methods to monitor burials without disturbing the specimen. However, it is known that the soil of a burial may resettle and cause cracking during the advanced stage of decomposition (Gleason, 2008). This is thought to be due to the loss of decomposition gasses creating a void in the grave, causing the soil to resettle and fill that void.

Factors of Surface Decomposition

Forensic taphonomic research suggests that different factors may affect the rate at which bodies decompose. For surface decomposition, factors that have an effect on the decomposition process are temperature, humidity, moisture, and insect activity. A large number of decomposition studies suggest that temperature is the most important variable acting on decomposition rates (Mann et al., 1990; Galloway, 1997; Komar, 1997; Archer, 2003; Megyesi et al., 2005; Wilson et al., 2007; Gleason, 2008; Parmenter and MacMahon, 2009; Simmons et al., 2010). Temperature affects the microbial processes that occur inside the body and outside of the body (Janaway et al., 2009). One of the microbial processes of decomposition is bacterial activity (Micozzi, 1991). Once a living organism dies, bacteria in the body converts blood sugar into ethanol, the act of converting sugar to alcohol could be considered part of the soft tissue

degradation process. Optimal bacterial cell division takes place in temperatures between 60 degrees Fahrenheit and 95 degrees Fahrenheit. In a climate with temperatures ranging from 60 degrees Fahrenheit to 95 degrees Fahrenheit, desiccation (mummification) of tissue would need to occur rapidly, from the time of death, for any soft tissue to remain. Research suggests that temperature may also affect the decomposition process via insect activity; in warmer climates insects are more active. Also, temperature can also affect the development of larvae, if the temperature is too cold, larvae, specifically maggots, will become slowed in their consumption of the carcass (Dorel et al., 2010.). Furthermore, temperature can impede the process of insect succession. If the insect succession is inhibited or altered in anyway, there is a possibility the postmortem interval estimation based on the insects themselves and from the soft tissue changes (or lack thereof) may be biased (Galloway et al., 1997). Although not well understood or researched in a decomposition setting, humidity is thought to be a factor in the rate of decomposition (Mann et al., 1990; Micozzi, 1991; Gleason, 2008). A lack of humidity is also thought to affect insect activity by causing the soft tissue to dry out too quickly, rendering it unavailable for insect larvae.

Some research suggests that precipitation may also affect surface decomposition (Archer, 2003). It is thought that rainfall can accelerate loss of mass and shorten the stages of decomposition. The loss of mass caused by rainfall may occur by hastening the breakdown of skin, or by accelerating the leaching of bodily fluids. Also, rainfall may prolong moisture retention within the body itself, which would create a longer length of time in which insect larvae could feed. On the other hand, rainfall could retard the process of decomposition for surface specimen, because heavy rainfall could wash away the insect larvae that are feeding on the carcass and/or halt the laying of new eggs (Mann et al., 1990).

The final factor of decomposition rate of surface finds is insect activity itself (Payne, 1965; Mann et al., 1990; Biavati et al., 2010; Dourel et al., 2010; Simmons et al., 2010). Insect activity is important to the decomposition process because insect larvae consume a large percent of soft tissue (Mann et al., 1990). In addition, a large mass of larvae generates a significant amount of heat on their own, which in turn could increase the heat of the body, and therefore increase the rate of decomposition (Bachmann and Simmons, 2010).

Factors Affecting Burial Decomposition

Burials are generally more difficult to find, due to the fact that the skeletal remains are buried to cover up criminal activities; therefore, what should forensic anthropologists look for suggesting a burial? One of the first indicators of a burial is the appearance of recently disturbed soil. Specifically, a forensic anthropologist should look for a mound of soil, which would be caused by excess soil from displacement by the body (Gleason, 2008; Dupras et al., 2010). The process of burying the body most likely causes a mixing of different soil strata, causing light and dark colored soils to be mixed together on the surface of the burial. The nutrients that are leached into the soil during the decomposition process can increase vegetation growth, over the burial site (Dupras et al., 2010). This new growth of vegetation can also appear to be a more vibrant green color than the vegetation of surrounding areas. However, a burial can have the opposite effect of the vegetation directly on top of the burial, if the nutrients from decomposition do not reach the roots of the vegetation. Along with new greener growth of vegetation, the type of vegetation may also change to more grasses and other opportunistic plants. Animal activity can also be a sign of a burial with increased activity of scavenging animals, such as Canids.

Decomposition of buried individuals is affected by temperature, humidity, burial depth, possible insect activity, and edaphic parameters (soil characteristics) (Micozzi, 1991; Turner and

Wiltshire, 1999; Dent et al., 2003; Wilson et al., 2007; Haslam and Tibbet, 2009; Janaway et al., 2009; Bachmann and Simmons, 2010; Carter et al., 2010; Schotsmans et al., 2011). In the instance of buried remains, both ambient temperature and soil temperature are variables of the decomposition process. Ambient temperature affects the decomposition process, because it effects changes in the temperature of the soil (Janaway et al., 2009; Bachmann and Simmons, 2010; Schotsmann et al., 2011). Although soil temperature is less susceptible to temperature fluctuations than that of the surface, the more shallow a grave is, the more susceptible the body becomes to the ambient temperature. Temperature also affects the microbial processes of decomposition that occur naturally within the carcass and within the surrounding soil (Janaway et al., 2009). As mentioned above, optimal bacterial cell division takes place in temperatures between 60 degrees Fahrenheit and 95 degrees Fahrenheit; therefore those temperatures will increase microbial processes of buried remains (Micozzi, 1991). Also, as stated above, ambient temperature can affect the processes of insects, which are known to be able to penetrate a burial and access decomposing remains (Bachmann and Simmons, 2010). However, internal temperature of the body must also be taken into consideration because possible insect activity, along with the natural microbial processes can increase body temperature (Micozzi, 1991).

It has been suggested that humidity affects the decomposition of burials the same way that it affects surface remains. Specifically, high temperatures will begin to dry out the body rapidly, while also increasing microbial activity; therefore when temperatures are high and microbial activity is high, the outcome is based on how the humidity causes the body to change (Micozzi, 1991). Research suggests that humidity may be one of the factors in adipocere formation, because the natural anaerobic conditions of the soil along with humidity make the perfect environment for the bacterial processes that create adipocere to thrive (Bachmann and

Simmons, 2010).

The depth of a burial also has an effect on the decomposition process due to temperature difference; temperatures in a burial are generally cooler than those on the surface (Schotsmans et al., 2011). As indicated above, those burials that are between one and two feet deep, are more susceptible to temperature variations than those that are deeper, allowing for skeletonization to occur within a few months to a year in shallower graves (Rodriguez et al., 1984). Depending on the depth of a burial, insect activity can be a factor of burial decomposition. It has been documented that insects generally cannot reach a body in a burial deeper than 19.7 inches (50 centimeters) (Bachmann and Simmons, 2010). Furthermore, surface vegetation may cause the decomposition process to occur faster, if the root system reaches the body.

The edaphic parameters that have an effect on burial decomposition are soil composition, pH, and its moisture content (Turner and Wiltshire, 1999). It has been suggested that clay soils may inhibit the process of decomposition by absorbing some enzymes or other microorganisms into the soil itself, not allowing for them to work on the carcass. These microorganisms are especially important in burial decomposition, because with a lack of insect activity, microorganisms from the soil and from the body itself are the main decomposing force in a burial environment (Carter et al., 2010). Furthermore, soils lacking clay, such as a loam, have the ability to drain water, subsequently leaving more oxygen available for microorganisms to thrive and continue the decomposition process (Turner and Wiltshire, 1999). Also, in soils where oxygen is available, decomposition is expedited, by helping to reduce decomposition gasses like ammonia, carbon dioxide, methane, and hydrogen sulphide from the body. In addition, soils that drain water well may limit the formation of adipocere by limiting the amount of available moisture for adipocere formation (Schotsmann et al., 2011). Moisture within the soil

can also slow the decomposition process, possibly by creating a burial environment where gas exchange cannot support microbial life (Carter et al., 2010). Unfortunately, although soil moisture is a recognized factor of burial decomposition, few studies have looked at that relationship (Jaggers and Rogers, 2009). The final factor that researchers believe affects burial decomposition is soil pH (Turner and Wiltshire, 1999). Soil pH is the alkalinity or acidity of soil. First, soil pH has an effect on the composition of the edaphic environment (Haslamm and Tibbett, 2009). For example, a low soil pH can inhibit bacterial processes on buried specimen. Also, a higher pH may increase the production of fungi. Acidic soils decompose bodies faster than those that are left in more alkaline soil (Tibbet and Carter, 2009). Furthermore, all soil pH values will become more alkaline once a body is in the soil, before it turns acidic.

Research Relevant to Surface Decomposition

Galloway et al. (1997) conducted decomposition research in arid Arizona, out of the University of Arizona. There were 189 cases selected based on the existence of last-seen-alive date and photographic evidence, using the last-seen-alive date and date of recovery to indicate length of exposure. All cases were separated by the stage of decomposition they were in when found; fresh, early decomposition, advanced decomposition, skeletonization and skeletal material. Galloway et al. (1997) observed that larvae in such environments take only four to seven days to complete larval stages. Also, the decomposition process appears to complete in one-fifth the time in the summer than it does in the winter. The summer poses a unique circumstance for larvae; eggs must be laid in the early stages of decomposition or the tissue will become dried out too fast for the larvae to ingest, so larvae may begin consuming the tissues on the inside of the body that retain moisture longer. Bloating may be seen between two and five days. Mummification of tissue begins around eleven days after death, and gradual loss of

mummified tissue to skeletal remains can take up to eight months. Arizona indeed does see seasonal differences in the decomposition process.

Carleen Gondor (2008) conducted decomposition research in Lubrecht Experimental Forest in Missoula County, 25 miles from the city of Missoula, at an elevation of 4,300 feet and in a 40 percent forest canopy with pine trees and different types of grasses and berry bushes. Gondor's (2008) research focused on the decomposition of grey wolves, mountain lions, black bears and whitetail deer. Gondor (2008) concluded that the most influential factor to the decomposition process of her research was temperature, but that precipitation and relative humidity also play a role in the decomposition process. In addition, it appeared that only summer and early fall exhibited definable stages of decomposition.

Two additional preliminary studies were conducted in the Lubrecht Experimental Forest in close to Gondor's (2008) research site. Both Dudzik (2009) and Parsons (2009) conducted their research to create a baseline understanding of decomposition in western Montana. Both researchers used Gondor (2008) procedures to secure the sight by enclosing the specimen in fencing and surrounding the enclosures with electric fencing. HOBO data loggers were also present for each of the research sites to record weather information.

Parsons' (2009) SS-1 pig was killed and placed at the site on 6 August 2008. SS-1 experienced the fresh stage for two days. SS-1 was bloated for two days. Early decomposition for SS-1 began on day four. Advanced stage started on the seventh day. Skeletonization occurred around day 110, where the remains were hard to the touch and the body was hollowed out.

Parsons' (2009) second specimen, SS-2 was killed and placed at the site on 13 October 2008. Parsons' (2009) SS-2 pig was in the fresh stage from day one to day fifty-five. Bloat for this carcass began on day 180. Parsons' (2009) concluded that the different months of deposition

created the difference in decomposition rates, and that ADD is not well suited for western Montana's estimates of PMI.

Parsons' (2009) sister study was conducted by Dudzik (2009) where data from SS-2 was compared to a pig that she did alone, SS-3. SS-3 was placed at its deposition site on 20 November 2008. SS-3 appeared to be in a state of stasis until April, when it was still in the fresh stage, the abdomen was purple in color. It was not until day 180 that the body began to bloat, the intestines subsequently pushed through the lower abdominal wall. Advanced decomposition began on 13 May 2009 and saw increased insect activity in a short amount of time. By the end of the study, the specimen had reached mummification with only 10 percent of the skeleton was exposed. Dudzik (2009) concluded that ADD is not adapted to the special climate of western Montana, and that the month of deposition affects the rate and process of decomposition.

Tiffany Terneny (1997) at The University of Montana conducted preliminary research on burial and surface decomposition. This area is near the Clark Fork River in Missoula, and had hemlock and four types of pine trees. The soil composition in that area is a gravelly loam. Terneny's (1997) main focus was to determine how long a human sized mammal would take to decompose in western Montana. The first pig was a mature, 160-pound pig and was buried 60 centimeters down, on 5 April 1996 and was covered with a plywood board. The second pig was a mature, 180-pound pig left on the surface on 5 April 1996, and was left open to scavenging. The buried pig was exhumed twice during its placement, once on 1 September 1996 and once again on 5 April 1997.

Terneny found that the surface pig remained in the fresh stage for three days, the bloat stage for seven days, the early stage for sixty-eight days, advanced stage for twenty-seven days, dry stage for 105 days, and remains stage for 157 days. The fresh stage was described as the

beginning of fly activity, change in skin color from pink to purple around the head and neck. At day thirty-three the skin began to slough off. During the advanced stage, the skin was a golden-brown color and beetles and maggots were still present. The dry stage was evident by its lack of insect activity except for a few beetles left on some dried skin. The remains stage had no insect activity and the exposed bones became bleached and dried.

Research Relevant to Burial Decomposition

Terneny's (1997) buried pig was first exhumed on 1 September 1996 and few plants were found once the plywood was removed. It was not until reaching twenty-seven centimeters that an odor became apparent, and as the depth continued, the soil became more moist and darker. Drosophilidae (fruit flies) were present within the body and the surrounding soil when uncovered. The first exhumation showed that all soft tissue remained intact. It was deduced that at this time, Pig one was still in the bloat stage. On the final exhumation, 5 April 1997 it appeared that the carcass was in the early stage of decomposition and the mouth and legs were skeletonized with associated dead maggots. Terneny (1997) concluded that temperature played an important role in the decomposition research that she conducted.

Wilson et al. (2007) conducted research in Yorkshire, England. The first site elevation was around 721 feet, in a horse pasture with a silty clay soil. The second site elevation was 1,400 feet with a gravelly clay (Moorland site). The last site was about 460 feet in elevation with a loam soil (Wooded site). All burials, using pigs as human proxies, were dug to the specification of 30 centimeters and 60 centimeters (about 1 to 2 feet) in depth. The pig specimens were on average about 20 weeks old and weighed around 143 pounds each. These pigs were observed for a two-year period. They concluded that there was little change between the temperatures in the burial and ambient temperatures, possibly due to the slower rate of decomposition. They also noted a

significant jump in soil pH, at the Moorland and Woodland sites. They believe that the soil temperature, pH levels and nutrient availability can alter the microbial conditions in the soil, which in turn alter the rate of decomposition of buried remains.

Carter et al. (2010) researched the decomposition of rats in Australia in three different soil types: clay soil, loamy sand, and sand. They found that the loamy sand and the clay soils retained much moisture, which slowed the decomposition process. The moisture probably resulted in the limitation of aerobic microbial metabolism. They also believed that the sand soil produced slow rates of decomposition due to the lack of nutrients in the soil for the microbes in the soil. Therefore, soil must have a balance of moisture and nutrients for microbes to perform at optimal rates.

Rodriguez and Bass (1990) conducted burial decomposition research in Tennessee, and buried cadavers one foot deep, two feet deep, four feet deep, five feet deep, and buried them during different times of year. They concluded that the decomposition of buried individuals is much slower than that of individuals on the surface. They also observed that the soil became more alkaline once the body entered the ground. The two main factors of burial decomposition in Tennessee are the slower process due to the lack of insect activity, and the cooler temperatures that were experienced in the graves. They indicate that there is a direct correlation between the rate of decomposition and the depth of the burial, due to the affect ambient temperature has on soil temperature and shallower depths.

Taphonomic changes are very important to law enforcement investigations, and can aid in the estimation of time since death of an unknown body. The unique climactic environment of western Montana creates a lot of variation in taphonomic changes. Also, because western Montana sees distinct separation between all four major seasons, seasonality can change the

outcome of taphonomic research. Although some decomposition studies have been conducted in western Montana, the collective research lacks decomposition information for late spring. Furthermore, taphonomic research in western Montana also lacks significant data for baseline burial decomposition.

Chapter 3 Materials and Methods

The main goal of this research was to contribute a baseline decomposition data in the unique environment of Montana in hopes that, ultimately, this information will assist law enforcement. This research was conducted in the Bitterroot Valley; which is 1,000 feet lower than Lubrecht Experimental Forest. Also, this research initiates a baseline decomposition dataset for buried specimens as well, which are expected to experience a different rate and perhaps sequence of decomposition relative to specimen on the surface. This study will help to outline the patterns of decomposition for surface finds and buried bodies.

Hypotheses

The first null hypothesis is that there is no difference in the rate and pattern of decomposition in western Montana and other areas of the United States. The first alternative hypothesis states that the rate and pattern of decomposition in western Montana are different from other areas of the United States. The second null hypothesis being tested is that the rate and pattern of decomposition will not vary between surface depositions and buried bodies. The second alternative hypothesis is that the rate and pattern of surface depositions are different from buried bodies.

Research Site

This research was conducted outside the Missoula area within the Bitterroot Valley, eight miles outside of Stevensville. This site is a privately owned ranch, geared towards raising cattle and growing hay. The site is at the bottom of a horse pasture where it levels out, and is not irrigated, unlike other pastures (Figure 3.1). The elevation of this particular site is 3,400 feet, a little over two hundred feet higher than Missoula, Montana (Web Soil Survey, 2013). This site's mean annual precipitation is between thirteen and nineteen inches. This site is near a collection

of trees; however not close enough to receive shade, thus the specimen was exposed the sun throughout the study. As seen in Figure 3.1, the vegetation of the area is mostly sagebrush. To prepare for the placement of the pigs, the burial area and the area for the dog kennel were cleared of sagebrush. The soil composition in this area is a silty loam (coarse-loamy alluvium), with clear stratification of soil and a starting pH of 6.5. The soil is also considered to be well-draining. These specimens were placed 20 feet apart to avoid insect cross-contamination, or confusing specimen smells. The surface pig, Pig S was placed in a premade dog kennel measuring 10 feet x 6 feet x 10 feet. To deter animal scavenging, the posts for the kennel were secured into the ground, along with electrification of the kennel of .08 Jules. For the buried pig, Pig B was buried in a pit approximately 80 centimeters wide, 122 centimeters long and 61 centimeters deep. To deter animal scavenging for Pig B, the sidewalls of the burial pit were lined in chicken wire and secured with commercial grade garden staples (Figure 3.2). A one-foot layer of soil was placed



Figure 3.1 Bitterroot Valley Site

on top of the pig, followed by a layer of chicken wire, which was held in place by an additional foot of soil laid on top. The second layer of chicken wire was secured on the edges of the burial surface by metal all-purpose stakes. The burial site was then enclosed in five hot wires of the same .08 Jules that the dog kennel received, again in order to deter animal scavenging.

Research Cadavers

Domestic pigs (*Sus scrofa*) are often used in experiments to replace human cadavers. This is due to the fact that pigs and humans are very similar in several anatomical and physiological ways (Sullivan, et al., 2001). Specifically, pigs have similar skin thinness, hair abundance, and adipose levels, resulting in postmortem changes similar to that of humans. The pigs used in this study were purchased from the Giles Family Ranch, located in Fairfield Montana, after being



Figure 3.2 Pig B in situ on 5/26/12

dispatched. The pigs were placed in plastic tarps to prevent contamination during transportation to their deposition site. Pig S weighing about 200 pounds and was placed in a 10 feet x 6 feet x 10 feet prefabricated dog kennel at 5:19 pm on 26 May 2012. The dog kennel was then secured into the ground and electrified to hinder scavenging. Pig B weighed 200 pounds and was placed in the ground and buried at 7 pm on 26 May 2012. Pig B was buried in a 61 centimeter deep pit, with the sidewalls lined in chicken wire. Then soil was placed on top of the pig, a layer of chicken wire, and more soil, then a final layer of chicken wire. Five electrified hot wires, all to deter from any forms of scavenging, enclosed the entire burial area.

Data Collection

Data collection was based on the guidelines established by Gonder in 2008. For Pig S, site visits occurred on a daily basis, then on a once a week basis once changes stopped occurring. During each visit, the following variables were recorded: 1) the stage of decomposition, 2) bloat, 3) degree of odor, 4) internal temperature, 5) ambient temperature, 6) relative humidity, and 7) insect activity.

The stages of decomposition that were documented followed Galloway's (1997, pp 141) five stages of decomposition (1) fresh, (2) early decomposition, (3) advanced decomposition, (4) skeletonization, and (5) extreme decomposition. The descriptions of the five above listed stages, that were used to note Pig S' stage of decomposition, are from Galloway (1997, pg 141).

1. Fresh

- a. Fresh, no discoloration or insect activity
- b. Fresh burned

2. Early Decomposition

- a. Pink-white appearance with skin slippage and some hair loss

- b. Gray to green discoloration, some flesh relatively fresh
 - c. Discoloration to brownish shades particularly at fingers, nose, and ears; some flesh still relatively fresh
 - d. Bloating with green discoloration
 - e. Post bloating following rupture of the abdominal gases with discoloration going from green to dark
 - f. Brown to black discoloration of arms and legs, skin having leathery appearance
3. Advanced decomposition
- a. Decomposition of tissue proceeding sagging of flesh, caving in of the abdominal cavity, often accompanied by extensive maggot activity
 - b. Moist decomposition in which there is bone exposure
 - c. Mummification with some retention of internal structures
 - d. Mummification of outer tissue only with internal organs lost through autolysis or insect activity
 - e. Mummification with bone exposure of less than one half of the skeleton
 - f. Adipocere development
4. Skeletonization
- a. Bones with greasy substance and decomposed tissue, sometimes with body fluids still present
 - b. Bones with desiccated tissue or mummified tissue covering less than one half of the skeleton
 - c. Bones largely dry but still retaining some grease
 - d. Dry bone
5. Extreme Decomposition
- a. Skeletonization with bleaching
 - b. Skeletonization with exfoliation
 - c. Skeletonization with metaphyseal loss with long bone and cancellous exposure of vertebrae

The bloat of Pig S was measured by a tape measure being placed underneath Pig S at the time of deposition and was measured at each visit. An Oakton data logger probe was inserted in the pig, and uploaded to a computer on a monthly basis, which monitored the internal and ambient temperature and relative humidity. These variables were recorded to help determine what stage of decomposition Pig S was in at the time of the visit.

Insect traps were placed in the four corners of the dog kennel that Pig S was placed in. The insects were trapped in order to record the specific type of bugs that were present during each stage. The researcher used several books and decomposition bug flash cards to identify the specific bugs. The insect activity would then allow for a comparison of other research, to determine if the same insects were present on Pig S at the same stage as specimen in other studies.

A Primos time-laps camera recorded the activity of Pig S from dawn to dusk, in case something occurred while the researcher was not onsite. Pictures of Pig S were also take on a daily basis with a Nikon L100 camera, to keep record of the evidence for the stages of decomposition and to make it possible for future researchers to compare their research visually.

This data was collected in a standard format and recorded in a “rite in the rain” field notebook to keep notes legible through bouts of rain or snow. The data logger data was transferred to an Access database specifically designed for this research. This data was used to identify any possible correlation between ambient temperature, internal temperature, relative humidity, and the rate of decomposition for each pig.

Data collection for Pig B also included ambient temperature, internal temperature of Pig B and relative humidity using an Oakton data logger. This data was also used to identify any possible correlation between ambient temperature, internal temperature, relative humidity, and the rate of decomposition for Pig B. Furthermore, this data could also help to determine when, and for how long Pig B was in an active stage of decomposition. Monitoring of the burial soil was conducted by visual assessment of vegetation growth. The vegetation change of the burial site could possibly be a good indicator for law enforcement to use when looking for a burial. Also, pH testers were used to determine whether Pig B increased the soils acidity or decreased it.

Soil pH tests were conducted on a monthly basis, to allow for enough possible change to occur. A Munsell soil chart was used to determine if the presence of Pig B changed the color of the soil. Visual assessment of the burial site also looked for possible surface insect activity. Insect activity can exponentially increase the rate of decomposition, so the possible presence of insects at a burial can alter the outcome of research. Furthermore, animal activity was monitored with an infrared Primos game camera, and was compared to footage of the same area a month prior to the placement of Pig B. The change in patterning of animals could also help in the detection possible burials. Pictures of the burial site were also taken during every visit with a Nikon L100 camera to record the evidence for future research. Data for Pig B was recorded in a field journal that was based on a datasheet.

The exhumation of Pig B took place on 2 March 2013. The process for removing the remains followed the procedures set forth Dupras et al. (2006). The first step was to record and map the surface of the burial. This way the context of the burial was not lost, and could be looked at for future reference. The second step was to identify and examine the burial outline, by removing any debris, and scraping the surface soil (about 1 centimeter deep). Identification of a burial outline can be critical to law enforcement investigations, due to the fact that burial outline are always looked for, and if one was not present for Pig B's burial, it could indicate that burial outline are a poor indicator of burials in western Montana. The next step was to excavate the burial feature, removing one layer (5 centimeters) of soil at a time, and keeping the unit at the same depth. The soil that was removed, was screened for insect and rodent evidence, and was separated by layer. As state above, evidence of insect and rodent activity could significantly change to the natural rate of decomposition of a buried specimen. The depth at which there was any indication of decompositional smells was recorded, in order to give some indicator to

investigators as to how far a test pit should be dug before the first sign of a burial. The fourth step was to expose the remains, which was done with blunt tools such as ice cream scoops, wooden tools and brushes to reduce damage to the remains. Once the remains were fully exposed, they were mapped in place. Scale based maps can help preserve the burial in situ and preserve that information for future research. All the above-mentioned information obtained from Pig B was used to determine the state of the remains when they were recovered and possibly the stages of decomposition Pig B went through during the nine months it was buried. Photographic evidence of the exhumation was taken throughout the day, and after each layer of soil was removed. This evidence in turn was used to compare to Pig S, along with other burial studies to determine how western Montana's burials differ or resemble the decomposition process other research, in turn helping create a baseline of buried decomposition in western Montana.

Analysis of data

The analysis of Pig S was conducted through comparing and contrasting its decompositional stages, climate, and insect data with other decomposition research. Also, data was assessed to determine how ambient temperature, internal body temperature and humidity affects the rate of decomposition. The role that insects played in the decomposition of Pig S was also analyzed to determine their breakdown of the soft tissue of Pig S, as well as the added heat they may have added to the decomposition process.

The analysis of Pig B also included a comparison between other buried decomposition research, and a comparison to Pig S. The temperature data was assessed to see if it could help indicate the time frame in which Pig B was in an active stage of decomposition. Furthermore, the change in vegetation, wild life activity, soil color and soil pH was analyzed to help determine

if those factors are applicable for law enforcement in western Montana to use when looking for a possible burial site.

Chapter 4 Results

The results are broken down into sections, one section for Pig S and another section for Pig B. The first and only section for Pig S is the decomposition process for Pig S in chronological order. Within this section, the stage of decomposition, the bloat, color, smell, insects and climate variables are given. The sections for Pig B are: animal activity, vegetation, soil and the exhumation process and outcomes. Climate data for Pig B is also given after the soil section.

Pig S Results

Decomposition Stage	Number of Days
Fresh	1
Early	9
Advanced	271
Skeletonized	*

Table 4.1 Pig S Decomposition Chart

* Pig S never reaches Galloway (1997) skeletonization stage, due to the retention of mummified tissue.

Decomposition Process

Pig S was fresh for one day, was in early decomposition for nine days, and was in advanced decomposition for two hundred and seventy-one days (See Table 4.1 and Figure 4.1). Pig S never reaches Galloway's (1997) skeletonization stage, due to the retention of mummified tissue over fifty percent of the body.

Pig S Fresh:

The fresh stage for Pig S only lasted one day. The average temperature on day one (5/26/12) was 44 degrees Fahrenheit with a relative humidity of 95 percent and an average internal temperature (probe inside pig) of 81 degrees Fahrenheit (Figure 4.2). Figure 4.3 shows, that only hours after death, parts of the abdomen became pink.

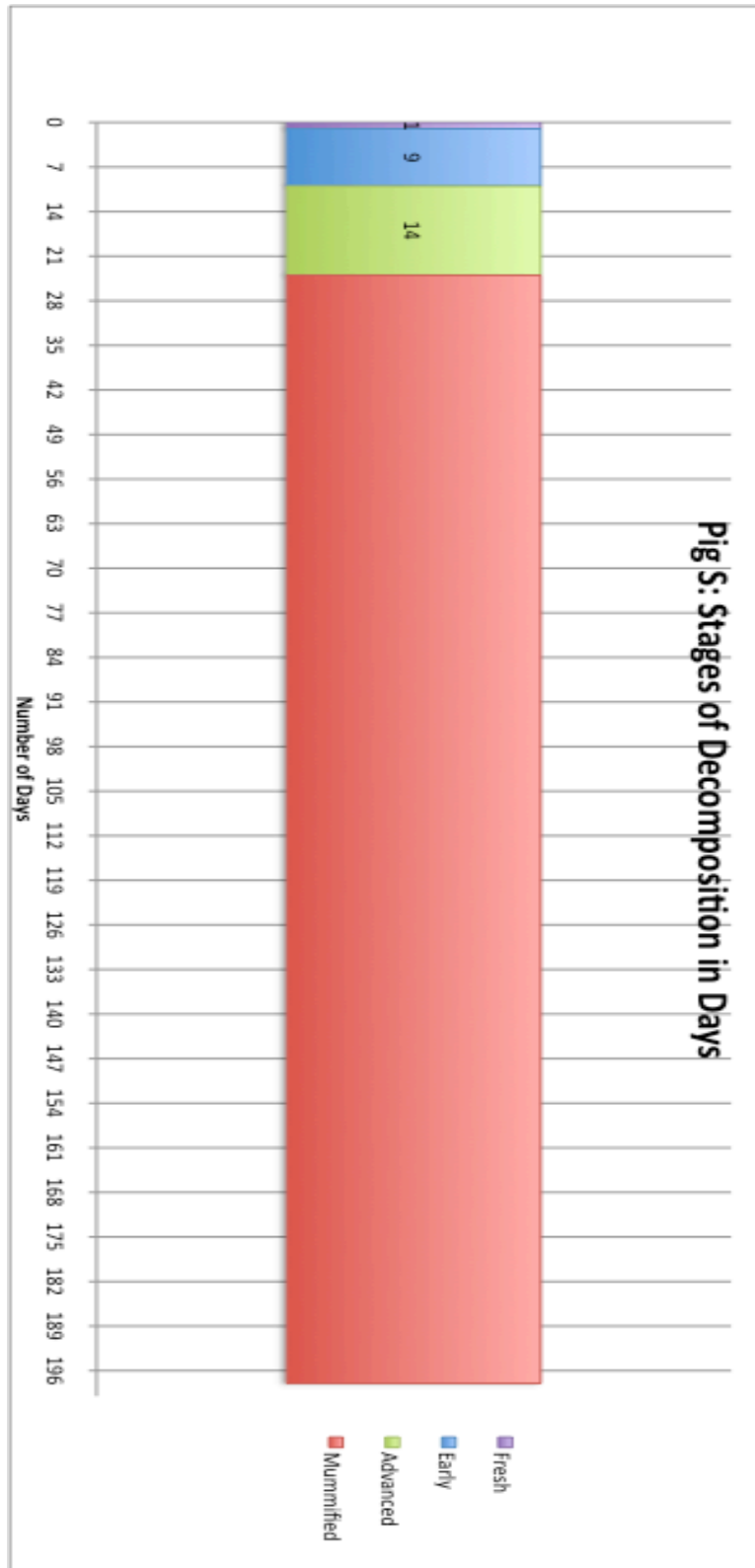


Figure 4.1 Pig S: Stages of Decomposition in Days

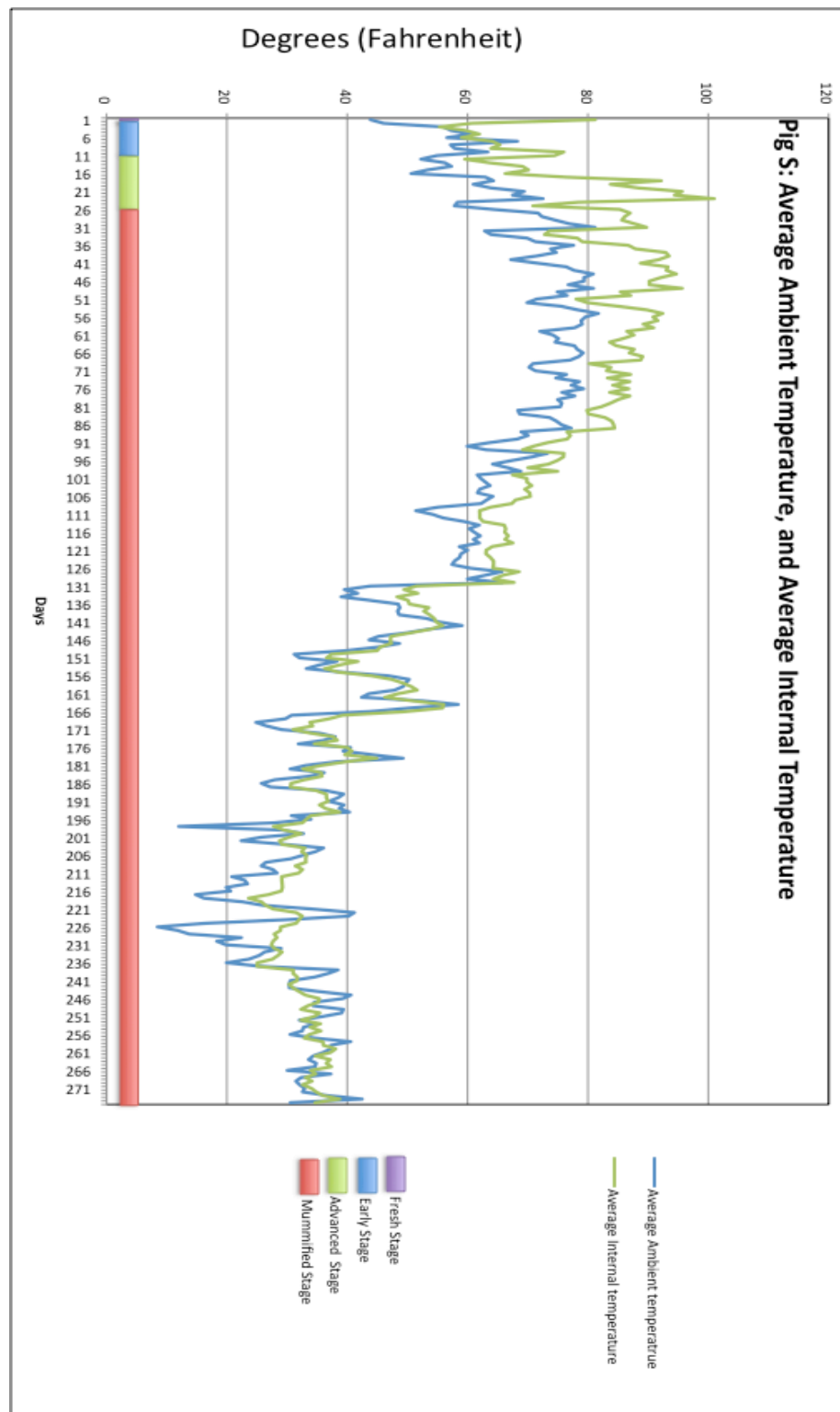


Figure 4.2 Average Ambient Temperature and Average Internal Temperature with Rates of Decomposition



Figure 4.3 Pig S: Fresh Stage Day 1: 5/26/12

Pig S Early decomposition:

The early stage of decomposition for Pig S lasted from day 2 to day 9. The average temperature for those 8 days was 58 degrees Fahrenheit, with an average humidity of 75 percent, and an internal average temperature of 63 degrees Fahrenheit. On day 2, Pig S started to turn dark pink on the inside of the legs, chest, neck and mandible, and was bloated to 127.1 centimeters.

On day 3, the discoloration of the inner legs, chest and mandible turned to a dark purple color, and the hip area turned to a bluish-green. Day 3 was marked by insect activity; fly activity began, and focused on the blood discharge from the nose and behind the right ear. Bloat was 127.5 centimeters. Day 4 had about 50 flies, over the entire body of Pig S and bloat was up to 132.4 centimeters. Dark purple discoloration was present on the medial aspect of the

legs. The chest mandible remained dark purple, while both sides of the hip area turned black and blue, and the backside of the right ear turned black.

On day 5 the dark purple discoloration of the chest, legs and mandible turned blue and black, and an organ began to push its way out of the anal cavity. The bloat on day 5 increased to 133.1 centimeters.

On day 6, 2 areas of fly eggs were visible in mouth, and on the lower left mandible. The chest, legs, back and mandible coloration changed to a greenish black hue and the tongue turned green (Figure 4.4). The smell of Pig S became noticeable from about 18 feet away, although it was a mild smell.



Figure 4.4 Pig S: Early Stage Day 6: 5/31/12

The organ still continued to protrude from the anal cavity. Places of thinning skin were also visible between the 2 back legs on the ventral surface. The bloat on day 6 was 135.9 centimeters.

By day 7 there were hundreds of flies present, more eggs were laid behind the right ear and maggots began to hatch in the mouth. The discoloration of the ventral and dorsal aspects appeared to remain the same. Additional pink skin thinning areas began to form on the ventral aspect of the abdomen, between the two back legs. The organ remained distended from the body through the anal cavity, but did not protrude out farther. There were a few beetles also present at the sight, which appeared to be a Histeridae (hister) beetles. The bloat on day 7 was 136.2 centimeters, and the smell of the pig was mild and not noticeable unless in a 4 foot range. At around 3:31 pm on day 7 (6/1/12) the large and small intestines extended from the right side of Pig S, just below the rib cage (Figure 4.5).

On day 8 the intestines that had protruded out the day before, became deflated and discolored. The discoloration of the ventral lower abdomen became more of a green color, while the neck and chest became black, with even darker black marbling. New, large masses of eggs were laid on the left side of the mental eminence, the right armpit, under the left leg, and in the deflated intestine. The masses of maggots found in the snout blood, tongue, and right ear increased in number. Adipocere and blood seemed to be leaching out of the back of the ear. The bloat at this point was 133.6 centimeters, and with no further protrusion of the organ out of the anal cavity. Also, there were Cleridae (red-legged ham beetles) and Staphylinidae (giant hairy rove beetles) beetles present on day 8.

Beginning on day 9 the maggots that were under the left chin hatched and a large mass of tinny maggots were found around the anal cavity, as well as in the tissue escaping from the right ear. Approximately 100 flies were present on day 9 and laid more eggs in the erupted intestines.

The smell on day 9 was a moderate decomposition smell and could be smelled from 9.1 to 10.6 meters away and the bloat was 133.2 centimeters.

Day 10 was the final day of the early decomposition stage, the top layer of skin on the right side of the face began to slough off, as well as the skin on neck, the chest down to the humerus, the lower ventral abdomen, and the spinal column to the head. Maggot activity was visibly occurring under the skin of the chest, from the exposed tissue on the back of the right ear around the entire skull to the left leg. Maggots were also on the medial portion of the left rear leg at the hip joint, down to the anal cavity as well as on the femur of the left rear leg, down to the patella. The bloat on day 10 was 133.8 centimeters with a moderate smell, sensed about 12.1 to 13.7 meters away.



Figure 4.5 Pig S: Intestinal Protrusion Day 7: 6/1/12

Pig S Advanced Decomposition:

Day 11 marked the beginning of the advanced stage of decomposition for Pig S. The bloat on day 11 decreased to 131.5 centimeters. The top layer of skin continued to come off, from almost the entire part of the body. Masses of maggots penetrated the palate, mandible, right eye socket, back of the right ear down the shoulder blade and around to the other side of the head, the left front leg, the exposed intestines and the hind areas by the anal cavity. The black marbling of the abdomen remained, while the tissue in between the back legs turned to red and orange. The teeth at this time turned to a pink color. At least 6 Cleridae (red-legged ham beetles) beetles took shelter right hind leg, just inferior to the most lateral digit, and a ladybug larva was found on the right front leg.

On day 12, there were about 50 flies present, and laying eggs on the medial aspect of the left hip. The maggot activity of the left front leg removed each layer of skin, to expose some of the muscle tissue. The mass of maggots from the shoulder blade, around the head to the left leg appeared to be increasing in number. The mass of maggots that was by the hindquarters seemed to have retreated into the anal cavity. The black discoloration of face, neck and chest extended to the left ventral aspect of the rib cage. Although the bloat of 131.5 centimeters remained the same, it appeared that the pig began to roll onto its back, rather than sit on its left side.

Day 13 had about 100 flies present on the Pig S. Also, the maggot masses had expanded, starting at the back by the scapulae and extending around the head, to the left leg, down the left side of the abdomen and stopping around the left hip area. The maggots began to infiltrate the inside of the abdominal cavity via the hole that was created by the protruding intestines. The maggot mass on the left leg began to expose the bones of the left leg. The discoloration of the lower abdomen, between the rear legs turned to a red/brown, yellow, black and grey. The right

scapula showed a circular pattern of discoloration with the outer most ring black, moving inwards it turned red, orange, and the inner most circle was green. The bloat on day 13 was 130.5 centimeters. Cleridae (red legged ham beetles) and Staphylinidae (giant hairy rove beetles) beetles continued to be present on the carcass. The smell on day 13 was a moderate ammonia smell.

On day 14 the bones of the left front leg became more exposed, and the bone of the mandible became exposed. The discoloration of the body remained the same from the day before, however there were some patches of white present on the upper abdomen, which could have been mold. There were tightly packed maggots within the left front leg tissue, as well as in the hole behind the right ear. The maggots on the left front leg opened a hole into the axial region. The bloat measurement on day 14 was 128.5 centimeters and there was a very strong ammonia smell.

Day 15 showed one cohesive mass of maggots that extended the entire outline of Pig S, with so many maggots on the left front leg that only the hoof was visible. The large number of maggots made measuring the bloat on that day impossible. The maggot mass in fact, became so large that they were touching the side of the electrified enclosure, and were being electrified. A plank of wood was placed between the kennel and the maggot mass to decrease the number of maggot being electrified. It also appeared that the rib cage and right shoulder blade were starting to sink in. The discoloration of the upper abdomen began to change to patches of red, orange, pink and black from the sternum to the anus. The odor on day 15 was a moderate ammonia smell that was noticeable from about 6 meters away.

Day 16 had an increase in maggot activity at the left abdomen, so much so that the measuring tape was no longer accessible or viewable, due to the large maggot mass (Figure 4.6)

However, it appears rain caused some of the maggots to be washed away from the body, and become caught in the pit traps. The discoloration of the body remained the same on day 16, and the smell was still moderate ammonia. There was also no fly activity.

By day 17 the hole that had been created in the back of the right ear had grown so much that it reached all the way down to the right scapula, and created a new hole just inferior to the right scapula. A large portion of the muscle tissue on the left front leg was gone, but tightly packed maggot masses remained in the left front leg and axillary area, and in the intestinal cavity and mouth. Also on day 17, Formicidae (red ants) began to carry away some of the maggots. The upper half of the abdomen continued to sink in and took on a leathery like feel. The discoloration of the body appeared to remain consistent, with a mix of red, black, brown, yellow and orange. However, the right side of the neck and mandible exhibited patches of white discoloration. Less than 20 flies were present on Pig S on day 17, and the odor was classified as moderate ammonia and could be smelled about 30.4 meters away.

By day 18 the humerus and radius of the left front leg could be seen through the maggot mass. Large maggot masses continued to work on the mouth and neck area, as well as the abdominal cavity hole, intestinal tissue, the axillary region, the scapular holes, and the medial portion of the right front leg. Day 18 was the first day in which the maggots started feeding on the dorsal side of the left hind leg. The left rear leg began to extend out straight, while the right leg remained flexed. Discoloration of abdomen remained the same, as did the white patches of discoloration of the right neck and mandible. The mild ammonia smell was still present on day 18 and was still noticeable 30.4 meters away.

Day 19 had a large reduction of the maggot mass that spanned the left side of the abdominal cavity. A majority of the maggot activity was focused on the hind end, the intestinal

cavity, the left front leg cavity and the medial aspect of the right front leg. The abdomen continued to cave in, with a clear outline of the rib cage visible. Another hole formed on the lower abdomen, just medial to the intestinal cavity. Although the white patches of discoloration were no longer found on the right neck and mandible, a similar white discoloration appeared on the sternum and upper portion of the rib cage on day 19. The lower abdomen still exhibited a mix of red, orange, yellow, brown, with the addition of purple and blue. There was also an increase in beetle activity on day 19, with Cleridae (red-legged ham beetles), Dermestidae (hide beetles), and Staphylinidae (giant hairy rove beetles) beetles all present. The smell of Pig S became a mild ammonia smell.



Figure 4.6 Pig S: Advanced Stage; Day 16: 6/10/12

Day 20 marked the beginning of the pupation stage for the maggots; so many maggots left the first day that they filled the hole that the northeast pit trap sat in. The maggots that went off to pupate were most likely from the upper half of Pig S, due to the fact that the amount of maggot on the upper half of Pig S decreased dramatically on day 20. The hole just medial to the intestinal cavity had very few visible maggots inside, but the hind end, intestinal tissue and dorsal left rear leg still had a fair amount of maggot activity. The caudal vertebrae became visible on day 20, with only a few fibers of soft tissue keeping them together. The discoloration of the abdomen was a mix of red, orange, yellow, brown, and black with a white film on the sternum and down the midline of the ribcage, and on the lateral portion of the left hind leg. Day 20 was the first time that there was any apparent bird activity on the kennel. The smell on day 20 was still a mild ammonia smell.

Day 21 saw an even larger decrease in the amount of maggots still present on Pig S, with a portion of the maggots going to pupate. The only mass of maggots left was small masses under the left side of the abdomen, small mass in the intestinal tissue, and a small mass left near the anal cavity. Bird activity seemed to increase at this time, with bird droppings on the kennel and on Pig S itself. The discoloration of the face and neck was brown with areas of white, grey and orange. The right front leg had taken on an orange color, with a white film covering it. The chest and abdomen was a mix of brown, orange, red, black, yellow, also covered in a white film. Cleridae (Red-legged ham beetles), Dermestidae (hide beetles) were present on Pig S. The odor on day 21 was mild ammonia with the return of mild decomposition smell.

On day 22 there was a large number of maggots traveling to the south end of the kennel to pupate. Only a few maggots remained in the cavity behind the right ear, under the mandible, in the intestinal cavity, and the rear end. Dermestidae (hide beetle) activity became more apparent

on Pig S, Cleridae (red-legged ham beetles) were still present in the kennel, but not viewed on the body on day 22. The discoloration of the face and neck was brown, light brown, orange and tan. The right front leg retained some orange color, and also changed to brown and yellow. The abdomen was black, brown, red, and orange, with the white film still present on the chest, upper abdomen and right hind leg. The smell on day 22 was classified as mild ammonia.

By day 23 there was only a few stray maggots left in and around the carrion. Although hide beetles and beetle larvae were found in the pit traps, none were visible on Pig S during the data collection time on day 23. The discoloration of the face and neck was brown, orange, tan, and red; the white film no longer covered this area. The right front leg became more white, and less orange. The right ventral ribcage was white and brown, more brown discoloration on dorsal surface. The upper surface of the abdomen was brown, orange and tan, and still covered in a white film. The lower abdomen was brown, black, dark orange and red. The left hind leg was brown with a white film, and the right hind leg was red and orange. The smell on day 23 was very mild ammonia. There was little change on day 24, with only a few maggots remained on or around the carrion. The discoloration of the body remained the same, as did the mild ammonia smell.

Pig S Mummified:

Although skeletonization of a majority of Pig S did not occur, by day 25 it had ceased to decompose, and remain in a static mummified state with no maggot or fly activity. Pig S would stay in this stage for the remaining 257 days, and change only a little due to beetle activity. On day 28 (Figure 4.7) little had changed in way of tissue coloration, or remaining mummified tissue: however, a large white and black spider was seen taking up residency within the carcass and the smell had all but dissipated. On day 43 it was visible that beetles and or beetle larvae

were beginning to consume the mummified tissue, creating two small holes in the tissue at the most inferior part of the right ventral ribcage. Both Cleridae (red-legged ham beetles) and Dermestidea (hide beetles) were present on Pig S during the visit on day 43. On day 48 there were newly formed holes in the mummified tissue on the right ribcage, the lower abdomen at the hip joints of both rear legs, in between the digits of the hind legs, and the carpals of the right front leg. Cleridea (red-legged ham beetles) and fuzzy brown beetle larvae were present on Pig S, on day 48. By day 79 the holes at the rear leg hip joints became large enough that the femur became visible through the mummified flesh. Figure 4.8 shows Pig S at the end of the research on day 281.



Figure 4.7 Pig S Day 28: 6/28/12



Figure 4.8 Pig S Final day, Day 281: 3/2/13

Environmental Factors:

Complete temperature data for Pig S can be found in Figure 4.2, with the average ambient temperature, average internal temperature. This graph shows that as temperature rises, humidity falls. Furthermore, Figure 4.9, depicts the average humidity with the rate of decomposition, perhaps suggesting that the lower the humidity the faster a body will reach mummification.

Pig B Results

Animal Activity:

A game camera was set up at the site 47 days prior to the pigs being placed there, to capture the animal activity before the pig placement. A vast majority of the animal activity prior to the placement of the pig was deer (Figure 4.10) rabbits, and horses from the field.

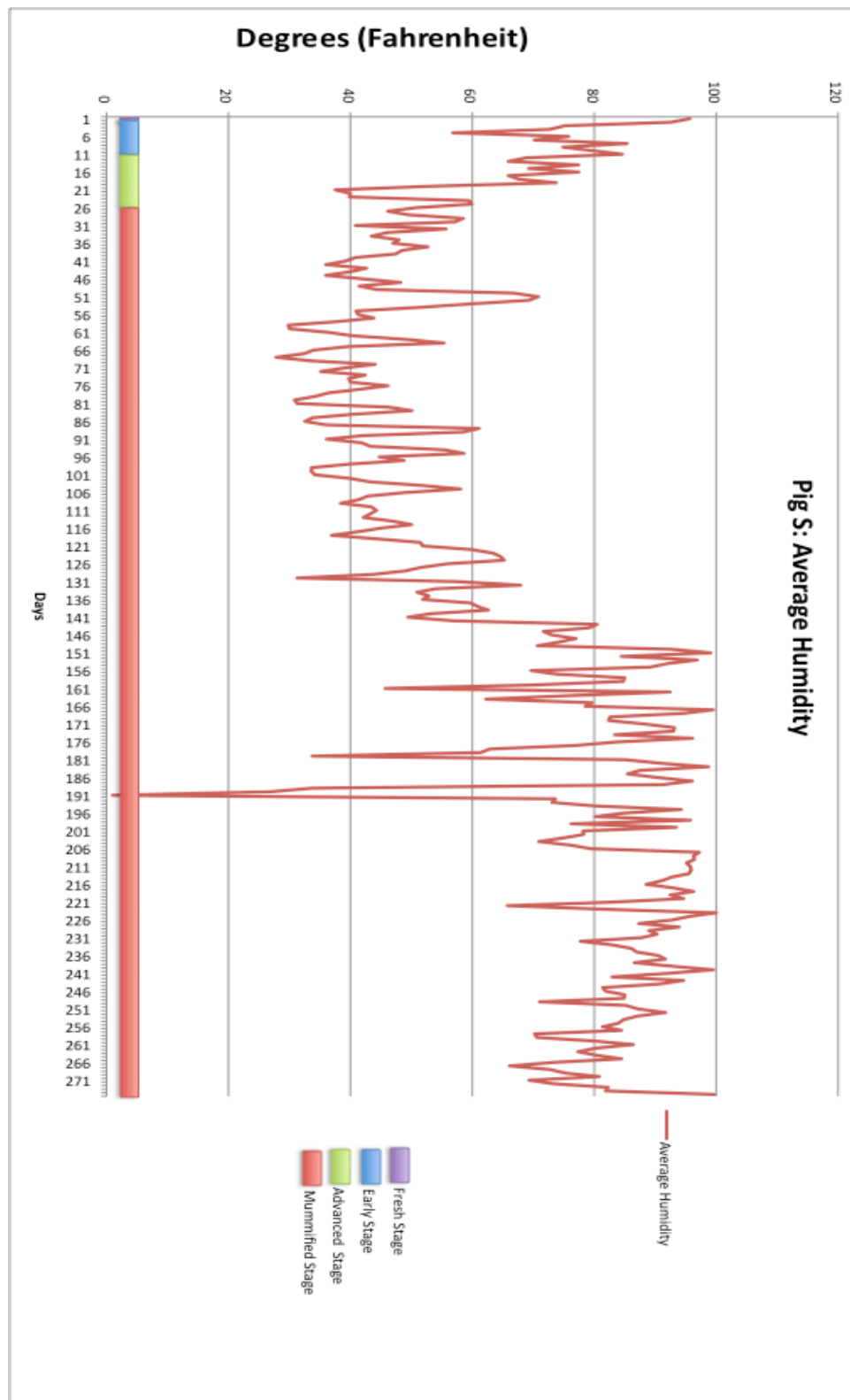


Figure 4.9 Pig S Humidity with Rates of Decomposition



Figure 4.10 Pig B Animal Activity

After the placement of Pig B, more scavenging animals were photographically captured as opposed to prey animals. The animals photographed after the pig placement were birds, foxes, skunks, barn cats, porcupine, a mouse, and more rabbits.

Vegetation:

The native vegetation of the area in which this research was conducted, was that of sagebrush. To prepare for the placement of Pig B, the burial area was cleared of sagebrush. By day 28 however, small patches of grass began to appear in the immediate area of the burial. On day 281 (the final day) there were at least 40 patches of grass present on the grounds surface on or in the surrounding area of the burial. This grass was a more vibrant green than any other

vegetation in that field as a whole. Patches of grass of a lighter green were also found underneath the ground surface, while skimming the burial plot.

Soil:

The beginning soil pH test showed that the soil on 5/26/12 (day 1) was 7.0, which is a pH of slightly alkaline. By day 8 the soil pH test showed that the pH had increased to 7.5 or higher (test only goes to 7.5), or alkaline. The soil would remain at this pH until the 281 day (last day) when the test read to between 7.0 and 6.5. The soil color was also monitored, although, high amounts of precipitation thought the nine months of research made it difficult to accurately measure the soil color of the burial. However, the soil of the burial was consistently measured at 2.5Y 6/2 for the darker color and 2.5Y 7/2 for the lighter color. The color 2.5 Y 6/2 is a light brownish gray and 2.5 Y 7/2 is a light gray. As seen in Figure 4.11, the soil of the burial could



Figure 4.11 Pig B Soil Coloration

easily be distinguished from the soil that is not part of the burial. For average ambient temperature, average internal temperature and average humidity for Pig B see Figure 4.12. The Figure 4.12 graph also shows the pattern that was seen in Pig S' climate data, as temperature rises, the humidity declines. Also, in Figure 4.12, it is noticeable that the rise of internal temperature, above the ambient temperature probably indicates that Pig B is in an active stage of decomposition.

Exhumation:

The exhumation of Pig B was completed on 2 March 2013. The skim of the top layer of soil showed a burial outline of a much lighter colored soil than that adjacent to the burial. Just below the surface skim, exhibited a lot of grass growth just below the surface of the burial and the surrounding area. There was one pupa casing found at 5 centimeters deep; however, the larva was still inside the casing and dead. Isopoda (pill bugs) became noticeable in the soil around 30.5 centimeters below the surface, and continued to be found, most significantly in the southwest corner of the burial. At around 30.5 centimeters within the soil, the smell of decomposition and ammonia became apparent through the remaining soil. At about 31 centimeters to 32 centimeters down, Histeridae (hister beetles) were encountered and they continued to be found throughout the soil and directly on top of Pig B. Between 33 centimeters and 34 centimeters patches of hair from Pig B were being excavated, with some of the hair also contained adipocere. At around 35 centimeters it was evident that there was a portion of very dry, different colored soil in the center of the burial pit (Figure 4.13). Also at this depth, there were holes in the soil, which had previously been packed down onto Pig B. Furthermore, around this level, several small black larva like bugs were found in the soil, and in one of the hoofs, as well as some white, maggot like insects clinging to roots in the soil. Once Pig B began to be distinguishable, a strong

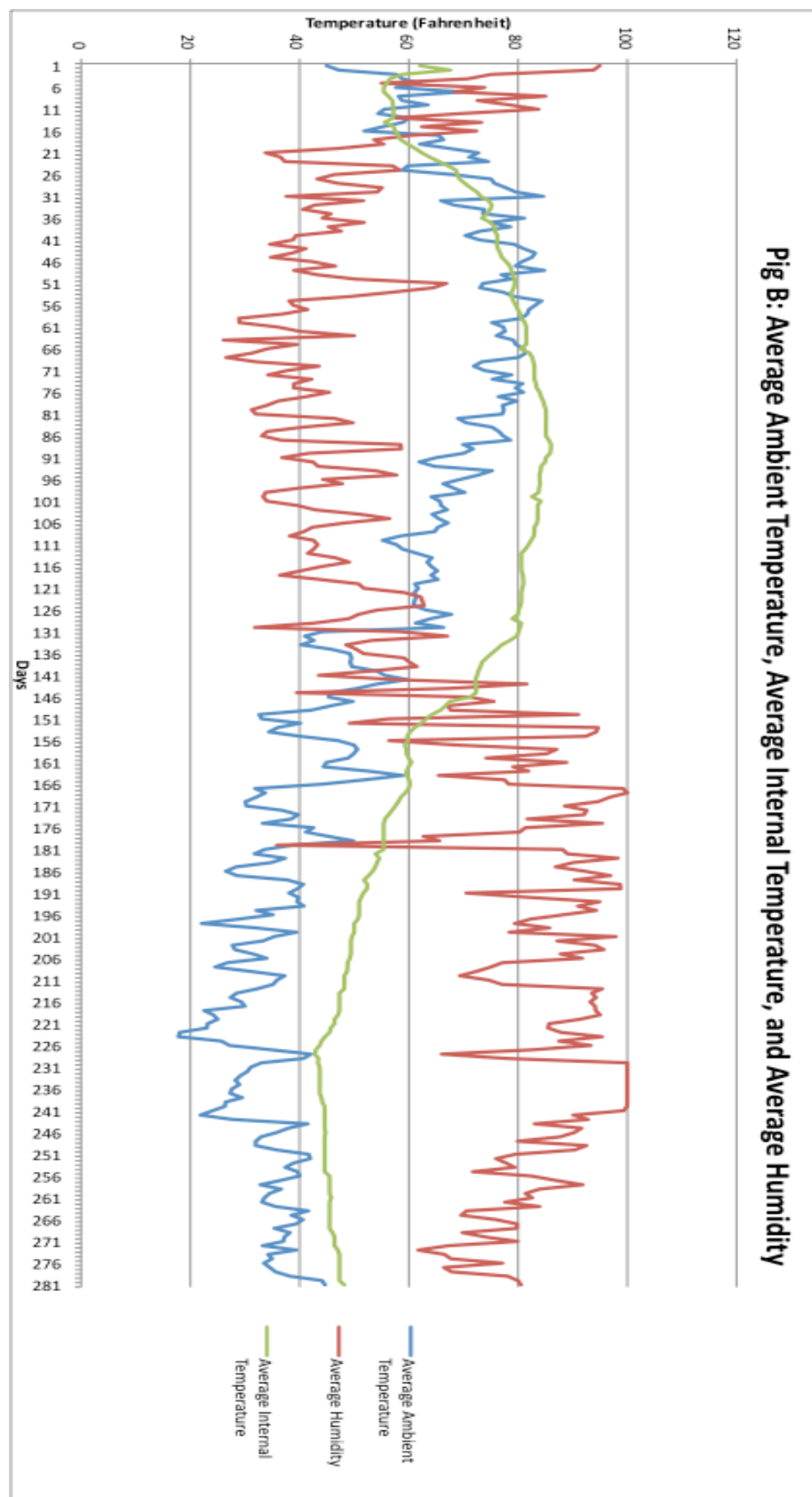


Figure 4.12 Pig B Average Temperature, Average Internal Temperature and Average



Figure 4.13 Pig B Exhumation at 35 Centimeters



Figure 4.14 Pig B Day 281; Fully Exhumed

ammonia smell became noticeable. Once Pig B became fully uncovered, the state of her condition became apparent (Figure 4.14). The head of Pig B was partially skeletonized the mandible, maxilla, and frontal were free of soft tissue. The neck area of Pig B appeared to be sunken in, with soft tissue still remaining. However, the right humerus was skeletonized and free of soft tissue. The right front leg was partially skeletonized, with soft tissue and adipocere adhering to the anterior surface. The left front leg was skeletonized and free of any soft tissue. The chest and rib cage of Pig B felt and looked like mummified tissue. However, the outline of the spinal column and the bottom of the stomach area had some tissue and adipocere and was extremely fragile. The lower abdomen had sunk in, where the stomach, spleen, liver, small intestine, and large intestine would be positioned. The right hind leg was similar to the right front leg, partial skeletonization and adherence of some soft tissue and adipocere. The left rear leg also mirrored the left front leg with full skeletonization. Figure 4.15 give a rough overview of what was found in each soil layer in Pig B's exhumation.

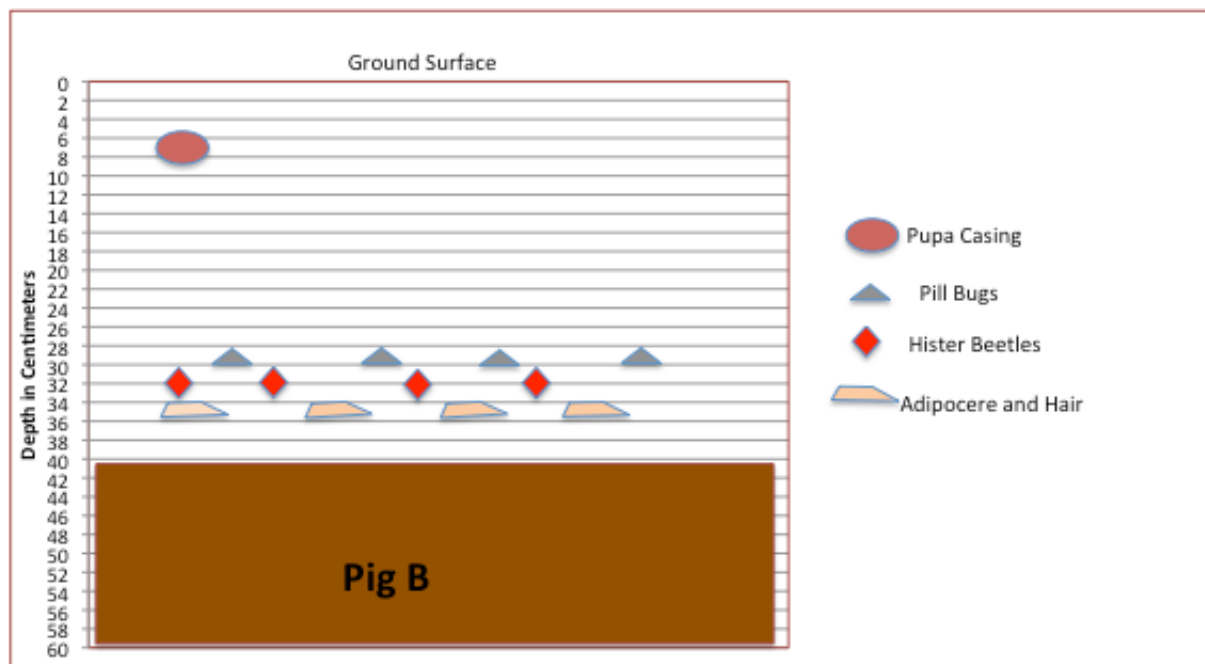


Figure 4.15 Pig B: Exhumed finds in soil levels

Based on the above results there is sufficient evidence to reject the null hypothesis that states there is no difference in the rate and pattern of decomposition in western Montana and other areas of the United States. The above evidence shows that the rate of decomposition is slower than the rate and of decomposition in places like Arizona, where mummification can occur within 11 days. The pattern of decomposition is also different in western Montana than other places in the United States, with the biggest difference being the retention of mummified tissue in western Montana, and not in other areas. Therefore, the alternative hypothesis, that the rate and pattern of decomposition in western Montana will differ from other areas of the United States, is accepted. Furthermore, the second null hypothesis that states that the rate and pattern of decomposition will not vary between surface depositions and buried bodies is also rejected. The difference in rate and pattern of decomposition can be seen in the comparison of Figure 4.2 and Figure 4.12, the surface decomposition rate went very quickly, where as the burial decomposition rate went much slower than that of the surface. Therefore, the alternative hypothesis the rate and pattern of burial decomposition in western Montana will differ from the rate and pattern of surface decomposition in western Montana, is accepted.

Chapter 5 Discussion

The purpose of this study was to test two hypotheses. The first hypothesis is that the rate and pattern of decomposition in western Montana will differ from other areas of the United States. The second hypothesis is the rate and pattern of surface deposition will differ from buried bodies in western Montana. A concurrent study, Spencer (2013) found that cold weather stasis could cause a carcass to appear fresh for months, which can skew the time of death for forensic investigations. For more information on western Montana cold weather stasis of decomposition, see Spencer (2013).

Comparison: Pig S to Pig B

It appears as though Pig S and Pig B did not decompose at the same rate or pattern as each other. As illustrated by Figure 4.1 the active portion of the decomposition process for Pig S was concluded by day 24. However, based on the information in Figure 4.12, the average internal temperature of Pig B rises above the average ambient temperature starting around day 60, indicating some microbacterial processes were occurring, and lasted until day 225. Assuming that Pig B decomposed in 165 days, then Pig B decomposed at a rate almost 7 times slower than Pig S. Similarly Carter et al. (2010) indicate that they believe that surface decomposition occurs 8 times faster than buried decomposition. Nonetheless, the final state of Pig S and Pig B were similar. Both pigs' partially skeletonization at the head (Figure 5.1), along with both left legs of Pig B skeletonized when only one left leg of Pig S being skeletonized (Figure 5.2 and Figure 5.3). In addition, both Pig S and Pig B retained a significant amount of mummified tissue on the abdomen. One of the only differences in the final state between Pig S and pig B, is that pig B had some adipocere formation, where as Pig S did not.

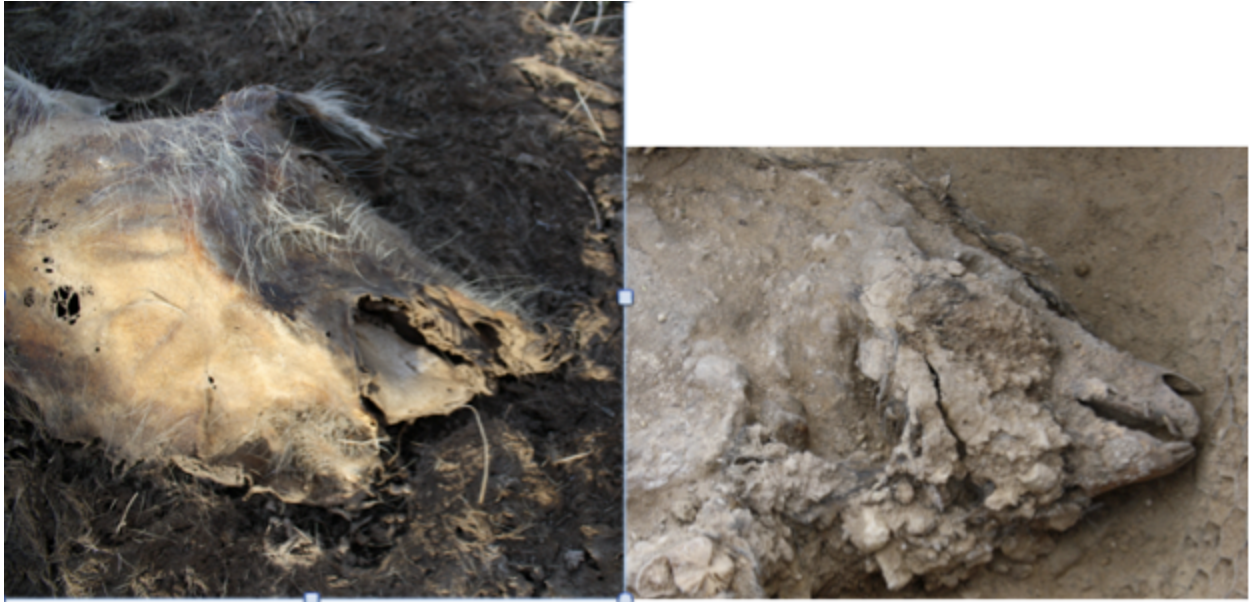


Figure 5.1 Pig S' Skull in Comparison with Pig B's Skull



Figure 5.2 Pig S' front legs in Comparison with Pig B's Front Legs



Figure 5.3 Pig S' hind legs in Comparison with Pig B's hind legs

Decomposition Pattern Comparison: Pig S

When the decomposition pattern of Pig S is viewed in terms of the stages of decomposition as set forth by Galloway (1997), a number of similarities were noted. Galloway (1997) fresh stage of decomposition is defined as no discoloration seen on any part of the cadaver's body. Although Pig S only stayed in the fresh stage for one day, it showed a majority of non-discolored during that period. The early stage of decomposition is described as discoloration of all parts of the body, including marbling, as well as the loss of bodily fluids from all orifices, and bloating of the abdominal cavity. Furthermore, family Calliphoridae (blow flies) begins to lay their eggs in the early stage of decomposition (Valdes-Perezgasga et al., 2010). The specificity of the discoloration in this stage is supposed to move from pink in color to green/grey, then to browns and blacks (Galloway, 1997). Pig S moved from a pink discoloration, to a purple discoloration, then to the common green/grey color, and ended the stage with some black marbling. Pig S also had blow fly activity including the laying of eggs in this stage. The advanced stage of decomposition is considered to be moist decomposition, and is characterized by the sagging of skin and the caving of abdominal cavity and areas of the face and neck, mummification of less than one half of the body, and large masses of maggots activity

(Galloway, 1997), belonging to the Calliphoridae (blow flies), Sarcophagidae (flesh flies), and Muscidae families (house flies) (Valdes-Perezgasga et al., 2010). Pig S went through moist decomposition for 14 days, in which its skin sagged, there were large masses of maggot activity and parts of the body became mummified. The flies and maggots on Pig S during this time were most likely of the Calliphoridae (blow fly) family. Skeletonization stage of decomposition is the exposure of greasy bones, although there may be some remaining soft tissue, bones with mummified tissue less than 50 percent (Galloway, 1997). In addition, arthropod activity of the Staphylinidae (rove beetle), Dermestidae (skin beetles), Cleridae (red legged ham beetles), Anthocoridae (flower bugs), Formicidae (ants), Soliphugae (spiders), Isopoda (crustacean), and Acari (mites and ticks) families can be seen (Valdes-Perezgasga et al. 2010). Usually at this point, fly larvae leave the carcass to pupate. Pig S did have insect activity from Dermestidae (skin beetle), Cleridae (red legged ham beetle) and Staphylinidae (rove beetle) activity beginning in the early stage of decomposition, through advanced decomposition. It appears as though the key arthropods are present during surface decomposition; however, it appears that western Montana lacks in variety of arthropods. Pig S begins to differ from Galloway's (1997) decomposition stages during the skeletonization stage. Pig S failed to reach a significant level of skeletonization (greater than 50 percent) in the 281 days following deposition. These findings represent the idea that if a deceased individual is placed in May in western Montana it will exhibit most of the patterns defined by Galloway's (1997). Although there are slight differences during the stages of active decomposition, there were enough similarities for the decomposition stages, through advanced decomposition, to be distinguishable in western Montana. This may become complicated when using Galloway (1997) skeletonization stage, because full skeletonization is not reached in western Montana, with the body staying essentially the same after advanced

decomposition due to mummification. Therefore, even though Galloway (1997) research was conducted in an arid environment, like western Montana, the stages of decomposition still do not work for western Montana.

The fact that this research has clearly defined stages of decomposition adds to the findings of Gondor (2008), which states that summer and fall also has clearly defined stages of decomposition. Although Parsons' (2009) research was conducted at a moderately higher elevation than that of this current study, both Parsons' (2009) SS-1 pig and this researcher's Pig S went through very similar decomposition processes. They exhibited similar discoloration patterns, insect activity patterns, and clearly defined decomposition stages. The main difference between Parsons' (2009) SS-1 and this study's Pig S is the duration of decomposition (Table 5.3), it appears that Parsons (2009) SS-1 pig decomposed at a faster rate than this studies Pig S. Dudzik (2009) SS-3 went through cold weather stasis retarding the rate of decomposition and therefore went through different decomposition rate than this study's Pig S (see Table 5.1).

Study	Deposition date	Fresh	Early	Advanced	Mummified
Parsons (2009) SS-1	8/6/2008	1	6	244	
Dudzik (2009) SS-1*	10/13/2008	180	54	44	-
Dudzik (2009) SS-3	11/20/2008	146	49	42	-
Tereny (1997) Pig 1	4/5/1996	3	7	95	105
Pig S	5/25/2012	1	9	14	257

Table 5.1 Current research decomposition stage duration in days vs Parsons (2009), Dudzik (2009) and Tereny (1997) * Dudzik (2009) SS-1 is Parsons (2009) SS-2

Galloway (1997) note in their research conducted in Arizona that bodies found in forensic cases experienced clearly separated decomposition stages. Although this research gives

a range in which most of the stages occur, it appears that the process of decomposition is faster in Arizona than it is in western Montana. However, the aridity of the Arizona environment does create mummification, similar to what was seen in this study. Galloway (1997) research noted the perforation of mummified tissue by (Dermestidae) hide beetles, as did this study. However, in Arizona, a carcass can reach skeletonization within a six-month period, whereas in this study, the mummified tissue remained throughout the nine-month period. It appears as though western Montana's spring has similar decomposition processes as Arizona, just at a slower rate, and with continued mummification which may be due to the lack of scavenging in this study, where as the forensic cases described by Galloway (1997) had at least some cases had been scavenged.

Terneny's (1997) research described a surface pig that was in the fresh stage for 3 days, the early stage for 7 days, the advanced stage for 95 days and skeletonization stage for the remainder of the study (Figure 5.3). The current study appears to have moved at a faster rate than Terneny's (1997), even though the bodies were placed out the same time of year. Nonetheless, the stages that this current study went through were very similar to those of Terneny's (1997), in terms of discoloration of the skin and insect activity. Terneny's (1997) study along with Parsons' (2009), Dudzik's (2009) and this current study suggest that when specimen do not go through cold weather stasis, there appears to be a clear pattern of decomposition stages, with the rate of decomposition being the most significant factor.

Temperature and Humidity: Pig S

Temperature and humidity had a strong effect on the decomposition process of this research. Figure 4.2 shows the average temperature, average relative humidity and average internal temperature for Pig S. The graph shows that this particular site in western Montana has a negative relationship between temperature and humidity. The graph shows that as the

temperature increase, the humidity decrease, and vice versa. This relationship is important in the creation of desiccated tissue. Mann et al. (1980) indicated this relationship in their research, stating that high temperature with low humidity leads to desiccated tissue. McKeown et al. (2011) indicates that desiccated tissue will remain on bodies in western Montana for long periods of time, if scavenging does not occur. Figure 4.2 illustrates that regardless of if the ambient temperature is high, or if the ambient temperature is low, the desiccated tissue remained. This is also true for figure 4.9, which shows that if the humidity is low the desiccated tissue will remain and when the humidity is high, the desiccated tissue will still remain.

There is also a significant difference in western Montana's high temperature versus low temperature. Figure 5.4 shows the temperature differences that were recorded from Pig S' data logger, throughout the research period. The temperature change from day to night in western Montana can change up to as much as 50 degrees Fahrenheit, whereas on average Tennessee's high and low temperatures differ only about 22 degrees Fahrenheit (Weather Channel, 2013). The weather pattern during the time of this study allowed for insects to be active, as warmer weather is necessary for insect activity. During Pig S' active stage of decomposition the weather was optimal for insects, especially for fly and maggot activity, as seen by the large maggot masses in Figure 4.6. The weather for a majority of this study was also optimal for cell division. Optimal bacterial cell division takes place in temperatures between 60 degrees Fahrenheit and 95 degrees Fahrenheit (Micozzi, 1991). There was only one day, throughout Pig S' active decomposition (early and advanced stages) that the maximum temperature was below the 60 degree Fahrenheit or above the 95 degree Fahrenheit threshold. Thus, there were favorable weather conditions for insects to continue their lifecycles relatively uninhibited.

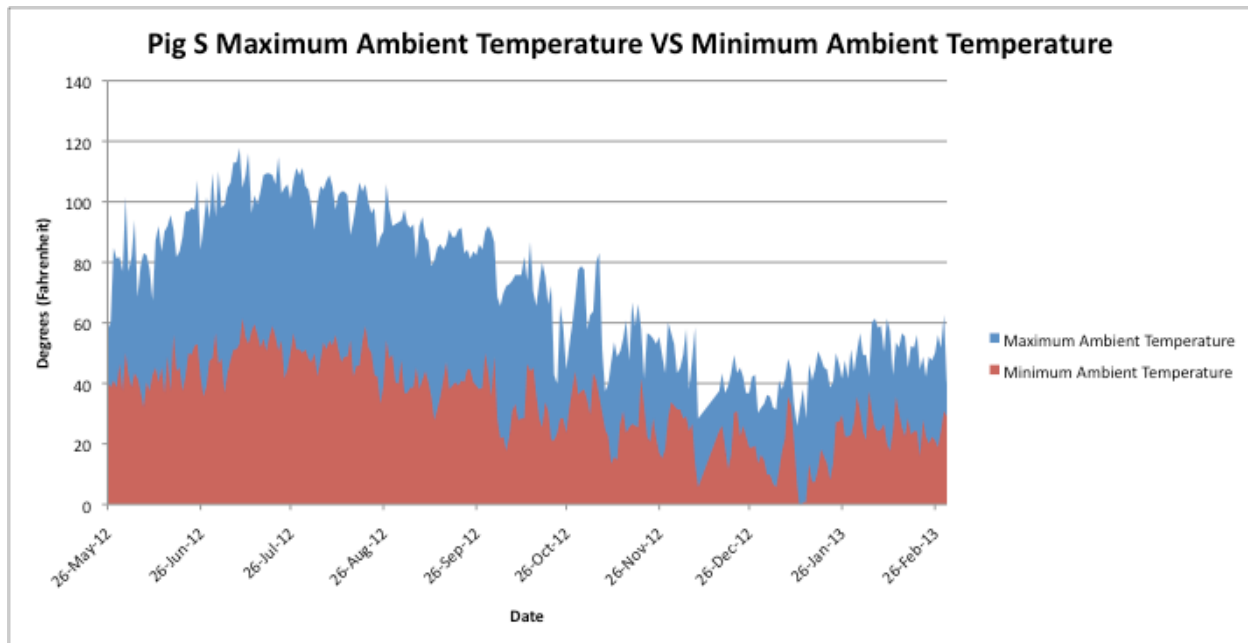


Figure 5.4 Pig S Maximum Temperature VS Minimum Temperature

Precipitation: Pig S

Precipitation did not have a strong effect on this study, which could be due to the fact that the deposition of Pig S occurred at the end of the rainiest season. There were only four days during Pig S' active decomposition (early and advanced stages) in which the precipitation at the research site was greater than 0.2 percent. As suggested by Archer (2003), moisture can increase the pace of decomposition through increasing the breakdown of skin and leaking of fluids. However, this did not seem apparent for Pig S, since the decomposition remained at a consistent rate. Another way in which moisture can affect decomposition, is that rainfall could retard the process of decomposition for surface carrions, because heavy rainfall could wash away the larvae that are feeding on the carrion, and/or halt the laying of new eggs (Mann et al., 1990). There was only one day (Day 16) in which there appeared to be enough rain to wash away some of the maggots, but not a significant number. Therefore, it does not appear that moisture had a great effect on the decomposition of Pig S, either to expedite it, or to retard it.

Insect Activity: Pig S

Most of the information on insect activity is found in the temperature and humidity section of this chapter, due to the strong correlation that exists between those variables.

Additionally, a large mass of larvae generates a significant amount of heat on their own, which in turn could increase the heat of the body, and therefore increasing decomposition rate (Bachmann and Simmons 2010). However, this concept is not clearly expressed from the data collected from Pig S. In Figure 5.5, the maximum temperature is graphed with the maggot mass temperature from Pig S, along with the internal temperature of Pig S, on the days in which the maggot masses were substantial enough to warrant a temperature reading. Some days the maggot masses do exhibit a higher temperature than the ambient and internal temperatures however, other days shows a lower maggot mass temperature and higher ambient and/or internal temperature. It would appear as though the maggot mass temperature did not have a strong effect on increasing the decomposition process of Pig S. Furthermore, it seems as though the maggot mass temperature of Pig S is correlated to the ambient temperature and internal temperature of Pig S, although how exactly and to what extent, is not clear from the current data.

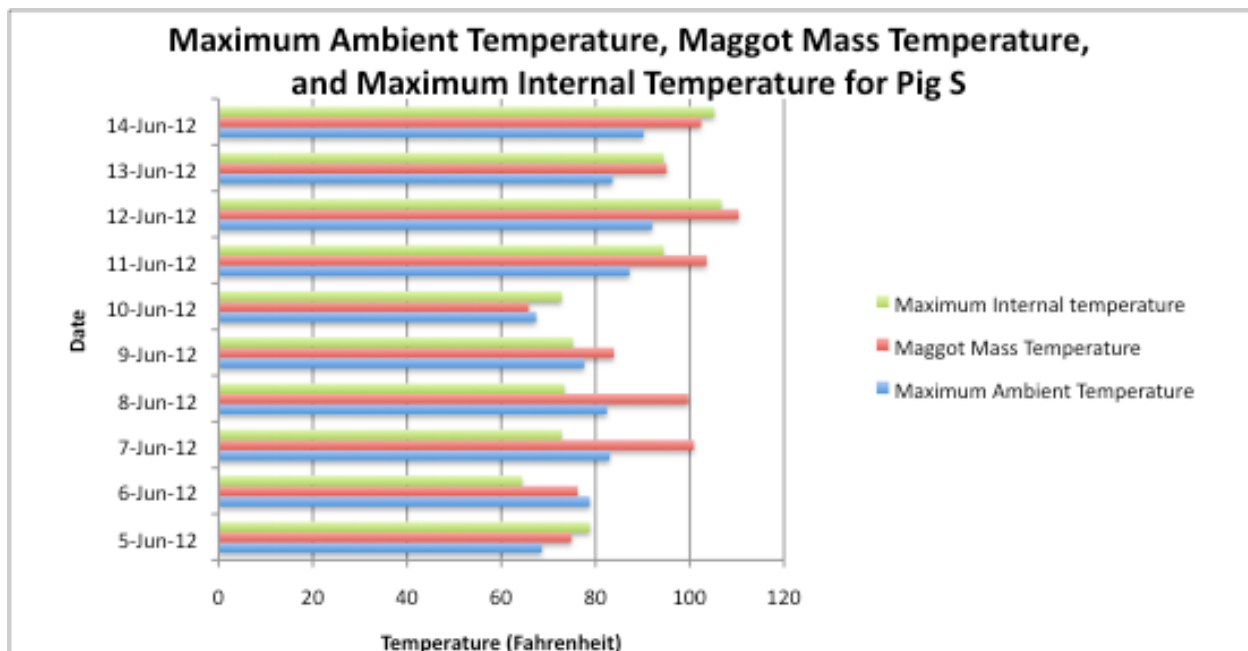


Figure 5.5 Pig S Maximum Ambient Temperature, Maggot Mass Temperature, and Internal Temperature

Decomposition Pattern: Pig B

Because of the process involved in a burial, decomposition cannot be visually observed, thus little is known about the specifics of burial decomposition process. Nevertheless, the soil of a burial may resettle and cause cracking, during the advanced stage of decomposition (Gleason, 2008). This is thought to occur when the decomposition gasses of the buried individual are released, and the body caves in, which the dirt resettles to fill the created void, in addition to normal soil settling. This was apparent throughout the duration of the study of Pig B. The first sign of cracking was seen on Day 4, but this sinking could have been due to resettling, from initial placement. However, the cracking was noted again on Day 50, Day 73, Day 93, and Day 134. This pattern, in combination with the weather information found in Figure 4.12, appears to be caused by the decomposition process of Pig B. However, the sinking of the soil was never significant enough to create a burial depression. The excess dirt that sat on top of the burial could

have caused this, creating a more level surface once the dirt began to sink in, as opposed to a depression being created.

Terneny's (1997) buried pig differed substantially in terms of surface indicators compared to those of Pig B's burial. There was a lack of vegetation at Terneny's (1997) burial site. However, this can probably be explained by the piece of plywood covering the burial site, possibly suffocating plants and keeping them from receiving the necessary sun to grow. Even though Terneny's (1997) pig was exhumed twice in a year period, there should have been enough time for plants to grow, based on the fact that Pig B's burial site saw vegetation beginning to grow in 22 days. Also, Terneny's (1997) pig was placed at a relatively similar depth as Pig B; however, it had maggots apparent on it. This could have been a natural process, or, as suggested, could have occurred due to the fact that the pig was exhumed 6 months after its initial deposition, rendering it vulnerable to fly egg-laying activity, which has been documented to happen in Bauchmann and Simmons (2010) research. Pig B did have some insect activity, although maggots were not present. Nonetheless, on the final exhumation of Terneny's (1997) pig, there was skeletonization of the skull, and legs. This is similar to the outcome of Pig B, where parts of the skull were skeletonized, along with the left front and hind legs. This indicates that there is a possible definable pattern of burial decomposition in western Montana, when sites have similar soil and moisture contents.

Indicators of Burial: Pig B

The first indicator that forensic anthropologists and law enforcement look for, when in search of a burial, is a burial depression, which is discussed earlier in this chapter. The next indicator is to look for is differential soil color mixture of soils surface (Gleason, 2008; Gondor, 2008; Dupras et al., 2010). This color mixture is caused by the soil in a particular area being

clearly stratified; however upon backfill, the stratified layers become mixed. This mixing of soil layers was present on the surface soil of Pig B's burial. This indicates that looking for mixed colors of soil is a relevant feature to look for in sites similar to the one used for this research.

The third factor that is looked for is a change in vegetation. The nutrients that are leached into the soil during the decomposition process can increase vegetation growth, over the burial site (Dupras et al., 2010). This new vegetation can be more of a vibrant green color, and consist of opportunistic plants and grasses. The site that Pig B was buried at was comprised almost entirely of sagebrush, with no other vegetation in the general area (see Figure 3.1 for a visual of the site pre-deposition). However, 22 days after deposition, a very vibrant green grass began to grow on top of the burial and in the immediate area (Figure 5.6). Therefore, investigators looking for burials in Western Montana, at sites similar to where this research was conducted, can look for vibrant opportunistic plants and grasses as an indicator of a burial.

A final factor that may be indicative of a burial nearby is the increase of scavenging animals in an area. This is due to the fact that scavenging animals are drawn to decomposing animals (Gondor, 2008). It would not be uncommon for animals to dig up the remains of buried bodies. This idea was reflected in this research. The animal activity that was seen at this site before the burial of Pig B was a majority of deer, rabbits, and horses. After the deposition of Pig B, there were foxes, skunks, barn cats, porcupine, and a mouse. It only appeared that there was possible attempted burrowing into Pig B during the first week after placement. This could be useful in the investigation of burials, if a park ranger or residence of an area see a change in the animals in that area. It could indicate a burial or even surface decomposition in the immediate area.



Figure 5.6 Pig B Vibrant Green Grass

Temperature and Humidity: Pig B

Ambient temperature and relative humidity affects burial decomposition processes, similar to the way that it affects surface decomposition. Ambient temperature affects the decomposition process, by changing the temperature of the soil (Janaway et al., 2009; Bachmann and Simmons, 2010; Schotsmann et al., 2011). In Figure 4.11 the data for average temperature, average relative humidity and average internal temperature of Pig B can be found. The graph shows that the internal temperature of Pig B correlates with the ambient temperature relatively closely. Wilson et al. (2007) conducted research in Yorkshire, England, looking at the decomposition of 20-week-old pigs in different soil types, at depths of 1 to 2 feet. Their research indicated that the ambient temperature and the internal temperature of the soil around the pig did not differ significantly. This was also the case with this researcher's Pig B. The only time there

was a substantial deviation from the ambient temperature was most likely when Pig B was in an active stage of decomposition. The climate information for Pig B also appears to have a negative correlation with relative humidity, as did Pig S' climate information. Temperature also affects the microbial processes of decomposition that occur naturally within the carcass and within the surrounding soil (Janaway et al., 2009). For maximum cell division, the internal temperature of Pig B should be between 60 degrees Fahrenheit and 95 degrees Fahrenheit. Based on the temperature data collected by the data loggers, there were 147 days in which Pig B's internal temperature was within that optimal cell division range. This means that over half the time frame for this study, consisted of optimal conditions for cell division to occur in Pig B. This prolonged period of optimal cell division could have assisted in the relatively quick decomposition of Pig B.

It has been suggested by Micozzi (1991) the difference in what actually transpires in decomposition processes is the effect of humidity. Buachmann and Simmons (2010) indicate that humidity can be important to burial decomposition by allowing the formation of adipocere. Their research indicates that bodies buried in more humid areas see adipocere formation. However, Pig B did exhibit a noticeable amount of adipocere formation. Figure 4.12 shows the average humidity for Pig B, and the humidity is not consistently high as it is in other place, such as Tennessee. Although the humidity rises as the temperature over winter decreases, the formation of adipocere would have most likely already occurred before winter. Therefore, the formation of adipocere must also be correlated with other factors, not controlled for in this study.

Depth: Pig B

The depth of a buried body can be important to forensic investigators for a number of reasons. The first reason being that burials that are between one and two feet deep, are more

susceptible to ambient temperature variations than those that are deeper, allowing for skeletonization to occur within a few months to a year (Rodriguez et al., 1984). This outcome can be seen for Pig B, in the Figure 4.11 that the temperature inside Pig B fluctuated closely with that of the ambient temperature. It was also noted that although the internal temperature would mimic the ambient temperature, the internal temperature would fluctuate with the ambient temperature less, once the body was in an active stage of decomposition. Based on the data in Figure 4.11, it would appear that Pig B was in an active stage of decomposition starting on Day 62, and continuing to throughout day 225. Depth can also affect possible insect activity of a burial as well; insects generally cannot reach a body in a burial deeper than 19.7 inches (50 centimeters) (Bachmann and Simmons, 2010). One pupa casing was found in the soil of Pig B's burial, at about 5 centimeters. However, it did not appear that this environment was suitable for the pupa, due to the fact that the maggot was still inside the casing, and dead. Furthermore, there were a number of beetles found around 33 centimeters and directly on top of Pig B, which appear to be Histeridae (hister) beetles. This is not considered unusual, because it falls within the 50-centimeter depth at which insects are generally found. Although adult Histeridae (hister) beetles can act dead, a number of them were placed in a plastic container and were not observed moving at any time. Therefore it was concluded that a majority, if not all of these beetles were dead. Histeridae (hister) beetles generally feed on maggots, however there was only evidence of one maggot in the entire burial. At around one foot, Isopoda (pill bugs) arthropods were found and some apparently were still alive. A majority of them were found in the southwest corner of the burial pit. These arthropods generally are attracted to carcass when in active decomposition, but do return in small numbers once decomposition has halted (Smith, 1986). Also, they are attracted to moist soils. It is hard to determine exactly why the Isopoda were present in the burial pit of

Pig B; however, it is most likely due to the fact that there was at least some moisture in the soil or decomposition occurring to attract them. Therefore, at the depth of two feet, the body was accessible by arthropods. Rodriguez and Bass (1990) indicate that there is a direct correlation between the rate of decomposition and the depth of the burial. It does, in fact, appear that the depth of the burial can alter many of the variables presented above.

Soil Characteristics: Pig B

The soil characteristics of a burial are especially important because microorganisms from the soil and from the carcass itself are the main factor of decomposition in a burial environment (Carter et al., 2010). The soil that Pig B was placed in is described by the U.S. Department of Agriculture as a silty loam. Silty loams have the ability to drain water, subsequently leaving more oxygen available for microorganisms to thrive on and continue the decomposition process (Turner and Wiltshire, 1999). Carter et al. (2010) researched the decomposition of rats in Australia in three different soil types, a clay soil, a loamy sand, and sand. They found that optimal soil conditions are not too moist, and soil that retains nutrients. The type of soil that is probably optimal for decomposition is a loam, it does not hold too much water, and holds on nutrients. Because Pig B was buried in a loam, there is a possibility that the soil type could have significantly attributed to the rate of decomposition. Furthermore, soil that Pig B was buried in was dry after the surface layers of soil were removed (Figure 4.10). In soils where oxygen is available, the decomposition is expedited, and also helps to reduce decomposition gasses like ammonia, carbon dioxide, methane and hydrogen sulphide from the body (Turner and Wiltshire, 1999). This could help explain the lack of a significant burial depression, if there was a reduction of decomposition gasses to begin with due to the type of soil, then not as many gasses would be expelled after Pig B bloated, causing a decreased void to be filled. Soils that drain water well,

may limit the formation of adipocere (Schotsmann et al., 2011). This complicates the finding that adipocere was in fact present on Pig B, which only covered part of the right legs, and along the outline of the vertebral column and ventral abdomen. However, there was an area of especially dry soil, directly over the abdomen of Pig B, and subsequently the area in which the most adipocere was found (Figure 4.13). It may be possible that the adipocere formation removed as much of the moisture possible from the soil in that direct area. However, although soil moisture is a recognized factor of burial decomposition, few articles look into that relationship (Jaggers and MacMahon, 2009); therefore making the understanding of these processes difficult to understand.

A final factor of burial decomposition process is soil pH. First, soil pH has an effect on the composition of the edaphic environment (Haslamm and Tibbett, 2009) and a high soil pH can expedite bacterial processes on buried specimen, causing the decomposition process to move more rapidly. Also, soil pH values will become more alkaline once a body is in the soil, before it turns acidic. The soil that Pig B was buried in had a starting pH of 7.0, slightly alkaline. By Day 8, the soil pH increased to 7.5 or higher (test only goes to 7.5), alkaline and remained so throughout the remainder of the study. It is suggested that pH levels increase during bloat and active decomposition and leveled off once decomposition had ceased. Therefore, the soil pH levels indicate that Pig B did go through active decomposition, possibly beginning around Day 8.

Chapter 6 Conclusion

The results presented in this study are part of a series of studies conducted to help in the understanding of decomposition in western Montana. This study contributes further to the understanding of surface and burial decomposition processes in western Montana. Weather data collected from studies such as this one, are important to the understanding of decomposition processes. This is because insect activity and bacterial activity, which are the main decomposers in surface and burial decomposition respectively, are greatly affected by temperature and humidity. Although researchers know that humidity is a relevant factor in the decomposition of both surface and buried specimen, more research is needed to better understand the role humidity plays in decomposition processes.

This study not only adds to the understanding of surface decomposition in western Montana, it is the beginning of burial decomposition understanding in western Montana. The findings of the surface pig, Pig S, are similar to what has already been described by Parsons' (2009) SS-1, SS-2, Dudzik's (2009) SS-3 and Terneny's (1997) Pig 2. This helps to illustrate the key visual clues to decomposition stages in western Montana. Although these stages may differ in duration, the month of deposition is a main factor in the rate of stages; the pattern of changes remains mainly consistent. This research also shows that the rate and process of decomposition in other areas, such as Tennessee are not applicable to western Montana; Tennessee's decomposition rate is much faster than western Montana, due to Tennessee's high temperatures and humidity. However, western Montana's decomposition process is similar to that of Arizona, due to similar climates; however, western Montana's decomposition occurs at a slower pace than that of Arizona, and sees continual mummified tissue in the absence of scavenging. However, the burial research of this study is only the second of its kind in western Montana. The results of

this studies burial decomposition shows that there are many variables that affect the decomposition of buried bodies. These variables are temperature, humidity, insect activity, depth of burial, and soil characteristics. This study shows that temperature is important to more shallow burials based on the fact that the body's temperature will fluctuate with the ambient temperature. Soil characteristics are especially important because the water table of the soil, and the soil pH can change the rate at which a body decomposes, either to expedite or to retard the process.

The materials and methods of this research are recommended for future decomposition studies as a baseline to work from. Although there appears to be a pattern of surface decomposition processes emerging for western Montana, further research should be conducted, especially to better understand the role that variables such as humidity play on the decomposition process. Also, a larger sample size, and every month represented would allow for greater comparison of the decomposition process in western Montana. Larger sample and every month of deposition represented also applies for further burial research. After a basic understanding of both surface and burial decomposition has been reached, then research can be conducted including other variables, such as the presence of clothing, and different burial depths. Overall, this research will aid law enforcement and forensic anthropologists to estimate time since death in both surface and burial finds.

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